U.S. DEPARTMENT OF COMMERCE
National Technical Information Service

PB-268 375

Oologah Reservoir Nowata and Rogers Counties, Oklahoma

National Eutrophication Survey, Las Vegas, Nev

Prepared for

Environmental Monitoring and Support Lab, Las Vegas, Nev

Mar 77

PB 266 375

U.S. ENVIRONMENTAL PROTECTION AGENCY
NATIONAL EUTROPHICATION SURVEY

WORKING PAPER SERIES

CORVALLIS ENVIRONMENTAL RESEARCH LABORATORY - CORVALLIS, OREGON
and
ENVIRONMENTAL MONITORING & SUPPORT LABORATORY - LAS VEGAS, NEVADA

REPRODUCED BY
NATIONAL TECHNICAL
INFORMATION SERVICE
U.S. DEPARTMENT OF COMMERCE
SPRINGFIELD, VA. 22161

Report
on
Coldgan Reservoir
Nowata and Rogers Counties
Oklahoma
EPA Region VI
Working Paper No. 502

With the cooperation of the
Oklahoma Department of Pollution Control
and the
Oklahoma National Guard
March, 1977

REPORT ON OOLOGAH RESERVOIR

NOWATA AND ROGERS COUNTIES, OKLAHOMA

EPA REGION VI

by

National Eutrophication Survey

Water and Land Monitoring Branch
Monitoring Applications Laboratory
Environmental Monitoring & Support Laboratory
Las Vegas, Nevada

and

Eutrophication Survey Branch
Corvallis Environmental Research Laboratory
Corvallis, Oregon

Working Paper No. 592

OFFICE OF RESEARCH AND DEVELOPMENT
U.S. ENVIRONMENTAL PROTECTION AGENCY

March 1977

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FOREWORD

The National Eutrophication Survey was initiated in 1972 in response to an Administration commitment to investigate the nationwide threat of accelerated eutrophication to freshwater lakes and reservoirs.

OBJECTIVES

The Survey was designed to develop, in conjunction with state environmental agencies, information on nutrient sources, concentrations, and impact on selected freshwater lakes as a basis for formulating comprehensive and coordinated national, regional, and state management practices relating to point source discharge reduction and nonpoint source pollution abatement in lake watersheds.

ANALYTIC APPROACH

The mathematical and statistical procedures selected for the Survey's eutrophication analysis are based on related concepts that:

a. A generalized representation or model relating sources, concentrations, and impacts can be constructed.

b. By applying measurements of relevant parameters associated with lake degradation, the generalized model can be transformed into an operational representation of a lake, its drainage basin, and related nutrients.

c. With such a transformation, an assessment of the potential for eutrophication control can be made.

LAKE ANALYSIS

In this report, the first stage of evaluation of lake and watershed data collected from the study lake and its drainage basin is documented. The report is formatted to provide state environmental agencies with specific information for basin planning [§303(e)], water quality criteria/standards review [§303(c)], clean lakes [§314(a,b)], and water quality monitoring [§106 and §305(b)] activities mandated by the Federal Water Pollution Control Act Amendments of 1972.

Beyond the single lake analysis, broader based correlations between nutrient concentrations (and loading) and trophic condition are being made to advance the rationale and data base for refinement of nutrient water quality criteria for the Nation's freshwater lakes. Likewise, multivariate evaluations for the relationships between land use, nutrient export, and trophic condition, by lake class or use, are being developed to assist in the formulation of planning guidelines and policies by the U.S. Environmental Protection Agency and to augment plans implementation by the states.

ACKNOWLEDGMENTS

The staff of the National Eutrophication Survey (Office of Research and Development, U.S. Environmental Protection Agency) expresses sincere appreciation to the Oklahoma Department of Pollution Control for professional involvement, to the Oklahoma National Guard for conducting the tributary sampling phase of the Survey, and to those Oklahoma wastewater treatment plant operators who provided effluent samples and flow data.

Dr. Denver Talley, Director, Oklahoma Department of Pollution Control; the staff of the Oklahoma Water Resources Board; and the staff of the Oklahoma State Department of Health reviewed the preliminary reports and provided critiques most useful in the preparation of this Working Paper Series.

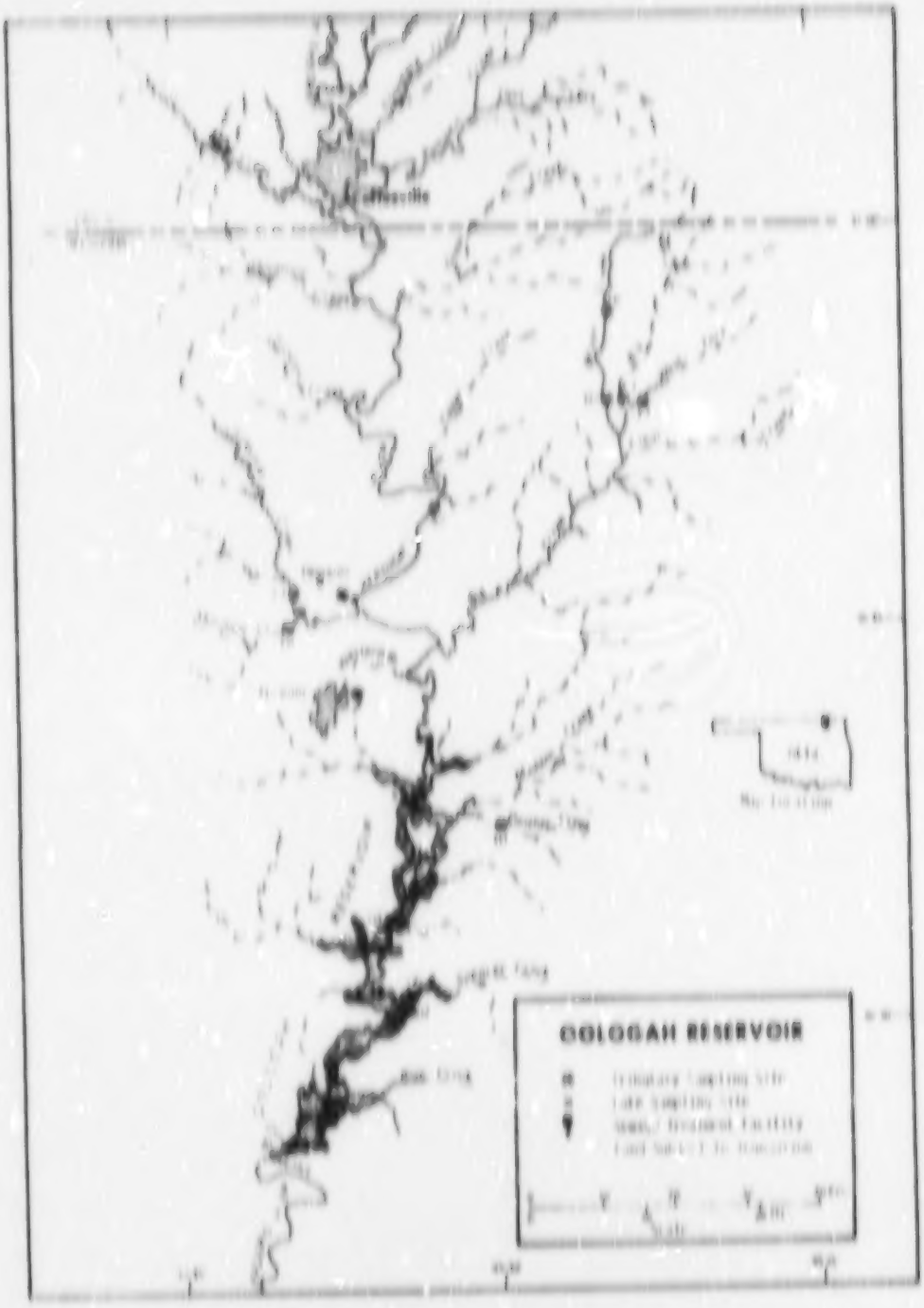
Major General John Coffey, Jr., the Adjutant General of Oklahoma, and Project Officers Colonel Curtis W. Milligan and Major James C. Haney, Jr., who directed the volunteer efforts of the Oklahoma National Guardsmen, are also gratefully acknowledged for their assistance to the Survey.

NATIONAL EUTROPHICATION SURVEY

STUDY LAKES

STATE OF OKLAHOMA

LAKE NAME	COUNTY
Altus Reservoir	Greer, Kiowa
Arbuckle Lake	Murray
Lake Elsworth	Caddo, Comanche
Lake Eufaula	Haskell, McIntosh, Okmulgee, Pittsburg
Fort Cobb Reservoir	Caddo
Fort Supply Reservoir	Woodward
Foss Dam Reservoir	Custer
Lake Frances	Adair
Grand Lake O' The Cherokees	Mayes, Delaware, Craig, Ottowa
Lake Hefner	Oklahoma
Keystone Reservoir	Tulsa, Creek, Osage, Pawnee
Oologah Lake	Nowata, Rogers
Tenkiller Ferry Reservoir	Cherokee, Sequoyah
Lake Thunderbird	Cleveland
Wister Reservoir	LeFlore


GOLOGAH RESERVOIR

REPORT ON OOLOGAH RESERVOIR, OKLAHOMA

STORET NO. 4017

I. CONCLUSIONS

A. Trophic Condition:*

On the basis of field observations and Survey data, Oologah Reservoir is considered eutrophic, i.e., nutrient rich and productive. Whether such nutrient enrichment is to be considered beneficial or deleterious is determined by the actual or potential impact upon designated beneficial water uses of each lake.

Chlorophyll a levels in the lake ranged from 0.3 µg/l to 15.5 µg/l, with a mean of 5.1 µg/l. Potential for primary productivity as measured by algal assay control yield was high, and Secchi disc visibility was very low. Of the 16 Oklahoma lakes samped in 1974 (including Lake Texoma), 6 had higher median total phosphorus levels, 3 had higher median inorganic nitrogen values, and 4 had higher median orthophosphorus levels than Oologah Reservoir.

Survey limnologists noted the lake was extremely turbid, and did not report any problem algal blooms or aquatic macrophyte growths.

*See Appendix E.

B. Rate-Limiting Nutrient:

The algal assay results indicate that Oologah Reservoir was limited by available phosphorus at the times of assay sample collection (04/02/74, 10/21/74). The lake data indicate primary limitation by phosphorus at the other sampling times as well. However, the low productivity estimated from chlorophyll *a* levels is most likely limited by light penetration rather than nutrient availability.

C. Nutrient Controllability:

1. Point sources -

During the sampling year, about 2.0% of the total phosphorus load to Oologah Reservoir was contributed by point sources. The city of Nowata contributed 2.0%, and the city of Delaware contributed <0.1%.

The calculated annual phosphorus loading of 3.45 g $P/m^2/yr$ is approximately four times greater than Vollenweider's (1975) "eutrophic" loading for lakes with such volume and retention time. However, Vollenweider's model may not be applicable to lakes in which epilimnetic light penetration is severely reduced by the presence of suspended sediments in the surface waters. If, in fact, the nutrient contributions of the Verdigris River are largely nonpoint in nature, it does not appear likely that point source phosphorus control would result in any appreciable change in the trophic condition of the lake.

2. Nonpoint sources -

The total annual phosphorus load not attributable to nearby point sources accounted for 98% of the loading reaching the impoundment. The Verdigris River contributed 94.5%, and Wolf Creek contributed 0.4% of the total. Ungaged tributaries were estimated to have contributed 2.5%.

The Verdigris River had a phosphorus export of 41 kg/km^2/yr. This rate is much higher than the rates of other unimpacted tributaries to Oologah Reservoir, or to nearby Grand Lake o' the Cherokees.* Such inflation of background nutrient loading is probably due to unknown point sources upstream in Kansas rather than actual nonpoint contributions, but further investigation is needed to determine the location and significance of these possible sources.

*See Working Paper No. 589, "Report on Grand Lake o' the Cherokees".

II. LAKE AND DRAINAGE BASIN CHARACTERISTICS

Lake and drainage basin characteristics are itemized below. Lake surface area and mean depth were provided by the Oklahoma Department of Pollution Control; maximum depth was provided by the Oklahoma Water Resources Board. Tributary flow data were provided by the Oklahoma District Office of the U.S. Geological Survey (USGS). Outlet drainage area includes the lake surface area. Mean hydraulic retention time was obtained by dividing the lake volume by mean flow of the outlet. Precipitation values are estimated by methods as outlined in National Eutrophication Survey (NES) Working Paper No. 175. A table of metric/English conversions is included as Appendix A.

A. Lake Morphometry:

1. Surface area: 119.22 km^2.
2. Mean depth: 5.7 meters.
3. Maximum depth: 24.4 meters.
4. Volume: 679,554 x 10^6 m^3.
5. Mean hydraulic retention time: 109 days.

B. Tributary and Outlet;
(See Appendix B for flow data)

1. Tributaries -

Name	Drainage area(km²)	Mean flow (m³/sec)
A-2 Verdigris River	9,585.6	62.50
C-1 Wolf Creek	238.0	1.31
Minor tributaries and immediate drainage -	1,294.9	7.91
Totals	11,118.5	71.74
2. Outlet - A-1 Verdigris River	11,237.7	72.21

C. Precipitation:

1. Year of sampling: 129.4 cm.
2. Mean annual: 99.4 cm.

III. LAKE WATER QUALITY SUMMARY

Oologah Reservoir was sampled four times during the open-water season of 1974 by means of a pontoon-equipped Huey helicopter. Each time, samples for physical and chemical parameters were collected from ten stations on the lake* and from one or more depths at each station (see map, page v). During each visit, depth-integrated samples were collected from each station for chlorophyll *a* analysis and phytoplankton identification and enumeration. During the first and last visits, 18.9-liter depth-integrated samples were composited for algal assays. Maximum depths (expressed in meters) sampled are listed below:

Station Number	Maximum Depth
01	21.6
02	12.2
03	9.1
04	9.1
05	1.5
06	6.7
07	10.7
08	12.2
09	9.4
10	2.4

The results obtained are presented in full in Appendix C and are summarized in III-A for waters at the surface and at the maximum depth for each site. Results of the phytoplankton counts and chlorophyll *a* determinations are included in III-B. Results of the limiting nutrient study are presented in III-C.

*At the June sampling, Station 07 replaced Station 06, 08 replaced 03, 09 replaced 04, and 10 replaced 05.

F. Biological Characteristics

1. Phytoplankton -

Sampling Date	Dominant Genera	Algal Units per ml
04/02/74	1. Chroomonas	454
	2. Chryptomonas	380
	3. Melosira	228
	4. Dactylococcopsis	76
	5. Skeletonema	76
	Other genera	39
	Total	1,293
06/13/74	1. Melosira	86
	2. Nitzschia	86
	3. Scenedesmus	29
	Other genera	--
	Total	201
08/28,29/74	1. Melosira	567
	2. Cryptomonas	177
	3. Stephanodiscus	142
	4. Chroomonas	71
	5. Skeletonema	71
	Other genera	142
	Total	1,170
10/21/74	1. Chroomonas	3,283
	2. Cyclotella	406
	3. Cryptomonas	190
	4. Melosira	163
	5. Skeletonema	163
	Other genera	327
	Total	5,034

2. Chlorophyll a:

Sampling Date	Station Number	Chlorophyll a (µg/l)
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]

Sampling Date	Station Number	Chlorophyll a (µg/l)
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]

C. Limiting Nutrient Study:

1. Autoclaved, filtered, and nutrient spiked -

Spike(mg/l)	Ortho P Conc.(mg/l)	Inorganic N Conc.(mg/l)	Maximum Yield (mg/l-dry wt.)
a. 04/04/74 - Stations 01-03			
Control	0.035	0.610	13.4
0.05 P	0.085	0.610	18.4
0.05 P + 1.0 N	0.085	1.610	32.9
1.00 N	0.035	1.610	11.1
Stations 04-06			
Control	0.015	0.540	6.0
0.05 P	0.065	0.540	14.7
0.05 P + 1.0 N	0.065	1.540	24.0
1.00 N	0.015	1.540	7.5
b. 10/21/74 - Stations 01,02,07			
Control	0.025	0.439	1.8
0.05 P	0.075	0.439	12.6
0.05 P + 1.0 N	0.075	1.439	20.3
1.00 N	0.025	1.439	1.4

2. Discussion -

The control yields of the assay alga, Selenastrum capricornutum, indicate that the potential primary productivity in Okiogah Reservoir was high at the times assay samples were collected (04/02/74, 10/21/74). Highly turbid lake conditions severely restricted light penetration and are the likely reason that chlorophyll a values noted (page 10) did not reflect the high yield potential noted under assay conditions where light limitation is not a factor. There was a significant increase in yield over that of the control when orthophosphorus was added but a lack of yield response when nitrogen alone was added. The maximum increase in yield over that of the control was achieved with the simultaneous addition of both nutrients. Based on these results, phosphorus limitation is indicated.

The mean inorganic nitrogen to orthophosphorus ratios (N/P) in the lake data were 14/1 or greater on all sampling occasions, further suggesting primary limitation by phosphorus (a mean N/P ratio of 14/1 or greater generally indicates phosphorus limitation).

IV. NUTRIENT LOADINGS
(See Appendix D for data)

For the determination of nutrient loadings, the Oklahoma National Guard collected monthly near-surface grab samples from each of the tributary sites indicated on the map (page v). Sampling was begun in November 1974, and was completed in September 1975.

Through an interagency agreement, stream flow estimates for the year of sampling and a "normalized" or average year were provided by the Oklahoma District Office of the USGS for the tributary sites nearest the lake.

In this report, nutrient loads for sampled tributaries were determined by using a modification of a USGS computer program for calculating stream loadings. Nutrient loads indicated for tributaries are those measured minus known point source loads, if any.

Nutrient loadings for unsampled "minor tributaries and immediate drainage" ("ZZ" of USGS) were estimated by using the mean annual nutrient loads, in $kg/km^2/yr$, in Wolf Creek at Station C-1, and multiplying the means by the ZZ area in km^2.

The operators of the Delaware and Nowata wastewater treatment plants provided monthly effluent samples and corresponding flow data.

A. Waste Sources:

1. Known municipal -

Name	Pop.* Served	Treatment*	Mean Flow ($m^3/d \times 10^3$)	Receiving Water
Delaware	510	Stabilization pond	0.106	Verdigris River
Nowata	3,500	Trickling Filter	1.613	Western Branch/ Verdigris River

2. Known industrial -

Name	Product	Treatment**	Mean Flow** ($m^3/d \times 10^3$)	Receiving Water**
Peabody Coal #1	Coal	None	0.189	Madden Creek
Peabody Coal #2	Coal	Settling basin	0.189	Spencer Creek

*Treatment plant questionnaires.
**Oklahoma Department of Pollution Control, 1976.

B. Annual Total Phosphorus Loading - Average Year:

1. Inputs -

Source	kg P/yr	% of total
a. Tributaries (nonpoint load) -		
A-2 Verdigris River	388,860	94.6
C-1 Wolf Creek	1,810	0.4
b. Minor tributaries and immediate drainage (nonpoint load) -	10,360	2.5
c. Known municipal STP's -		
Delaware	75	<0.1
Nowata	8,255	2.0
d. Septic tanks* -	15	<0.1
e. Known industrial -		
Peabody Coal #1	Unknown	---
Peabody Coal #2	Unknown	---
f. Direct precipitation** -	2,085	0.5
Totals	411,460	100.0

2. Output - A-1 Verdigris River 159,885

3. Net annual P accumulation - 251,575

*Estimate based on 35 lakeshore residences and 4 parks.
**Estimated (see NES Working Paper No. 175).

C. Annual Total Nitrogen Loading - Average Year:

1. Inputs -

Source	kg N/yr	% of total
a. Tributaries (nonpoint load) -		
A-2 Verdigris River	3,791,695	89.5
C-1 Wolf Creek	46,190	1.1
b. Minor tributaries and immediate drainage (nonpoint load) -	251,210	5.9
c. Known municipal STP's -		
Delaware	315	<0.1
Nowata	19,580	0.5
d. Septic tanks* -	515	<0.1
e. Known industrial-		
Peabody Coal #1	Unknown	---
Peabody Coal #2	Unknown	---
f. Direct precipitation** -	128,710	3.0
Totals	4,238,215	100.0
2. Output - A-1 Verdigris River	3,743,220	
3. Net annual N accumulation -	494,995	

*Estimate based on 35 lakeshore residences and 4 parks.
**Estimated (see NES Working Paper No. 175).

D. Mean Annual Nonpoint Nutrient Export by Subdrainage Area:

Tributary	kg P/km²/yr	kg N/km²/yr
Verdigris River	41	396
Wolf Creek	8	194

E. Mean Nutrient Concentrations in Ungaged Streams:

Tributary	Mean Total P (mg/l)	Mean Total N (mg/l)
B-1 Panther Creek	0.066	1.328
D-2 Brush Creek	0.044	1.296
E-1 Big Creek	0.063	1.416
F-1 East Fork Big Creek	0.040	1.303
G-1 Norman Creek	0.048	1.396

f. Yearly Loadings:

In the following table, the existing phosphorus annual loading is compared to the relationship proposed by Vollenweider (1975). Essentially, his "eutrophic" loading is that at which the receiving waters would become eutrophic or remain eutrophic; his "oligotrophic" loading is that which would result in the receiving water remaining oligotrophic or becoming oligotrophic if morphometry permitted. A "mesotrophic" loading would be considered one between "eutrophic" or "oligotrophic".

Note that Vollenweider's model may not be applicable to water bodies with very short retention times or in which light penetration is severely restricted from high concentrations of suspended solids in the surface waters.

	Total Yearly Phosphorus Loading ($g/m^2/yr$)
Estimated loading for Golagh Reservoir	3.45
Vollenweider's "eutrophic" loading	0.83
Vollenweider's "oligotrophic" loading	0.42

V. LITERATURE REVIEWED

Oklahoma Department of Pollution Control. 1976. Water Quality Management Plan, Middle Arkansas River Basin. Oklahoma City, Oklahoma.

U.S. Environmental Protection Agency. 1975. National Eutrophication Survey Methods 1973-1976. Working Paper No. 175. National Environmental Research Center, Las Vegas, Nevada, and Pacific Northwest Environmental Research Laboratory, Corvallis, Oregon.

Vollenweider, R. A. 1975. Input-Output Models With Special Reference to the Phosphorus Loading Concept in Limnology. Schweiz. Z. Hydrol. 37:53-84.

VI. APPENDICES

APPENDIX A
CONVERSION FACTORS

CONVERSION FACTORS

Hectares x 2.471 = acres

Kilometers x 0.6214 = miles

Meters x 3.281 = feet

Cubic meters x 8.107×10^{-4} = acre/feet

Square kilometers x 0.3861 = square miles

Cubic meters/sec x 35.315 = cubic feet/sec

Centimeters x 0.3937 = inches

Kilograms x 2.205 = pounds

Kilograms/square kilometer x 5.711 = lbs/square mile

APPENDIX B

TRIBUTARY FLOW DATA

Reproduced from best available copy.

[illegible] FLOW INFORMATION FOR [illegible]

LAKE CASE #12 FLOWER LAKE

TOTAL [illegible] AREA OF LAKE(S) = 11237.7

[illegible]	SUBBASIN AREA	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
							SUBBASIN FLOWS(CFS)						
[illegible]	11237.7	35.41	36.07	73.42	143.36	244.48	247.25	111.57	25.67	52.11	55.22	28.11	23.24
[illegible]	4895.6	27.47	38.87	85.04	124.12	117.34	111.57	107.22	19.04	47.11	46.64	23.58	17.96
[illegible]	736.1	8.17	6.41	1.37	2.24	[illegible]	[illegible]	1.85	0.48	4.13	8.48	6.78	8.59
[illegible]	1484.1	3.19	5.34	7.1	13.31	24.42	12.46	9.23	2.13	5.31	5.88	4.13	3.41

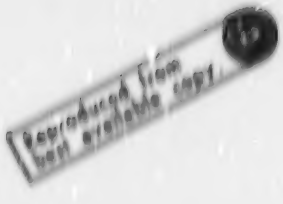
TOTAL SHORELINE AREA OF LAKE = 11237.7
SUM OF SUBBASIN AREAS = 11237.7

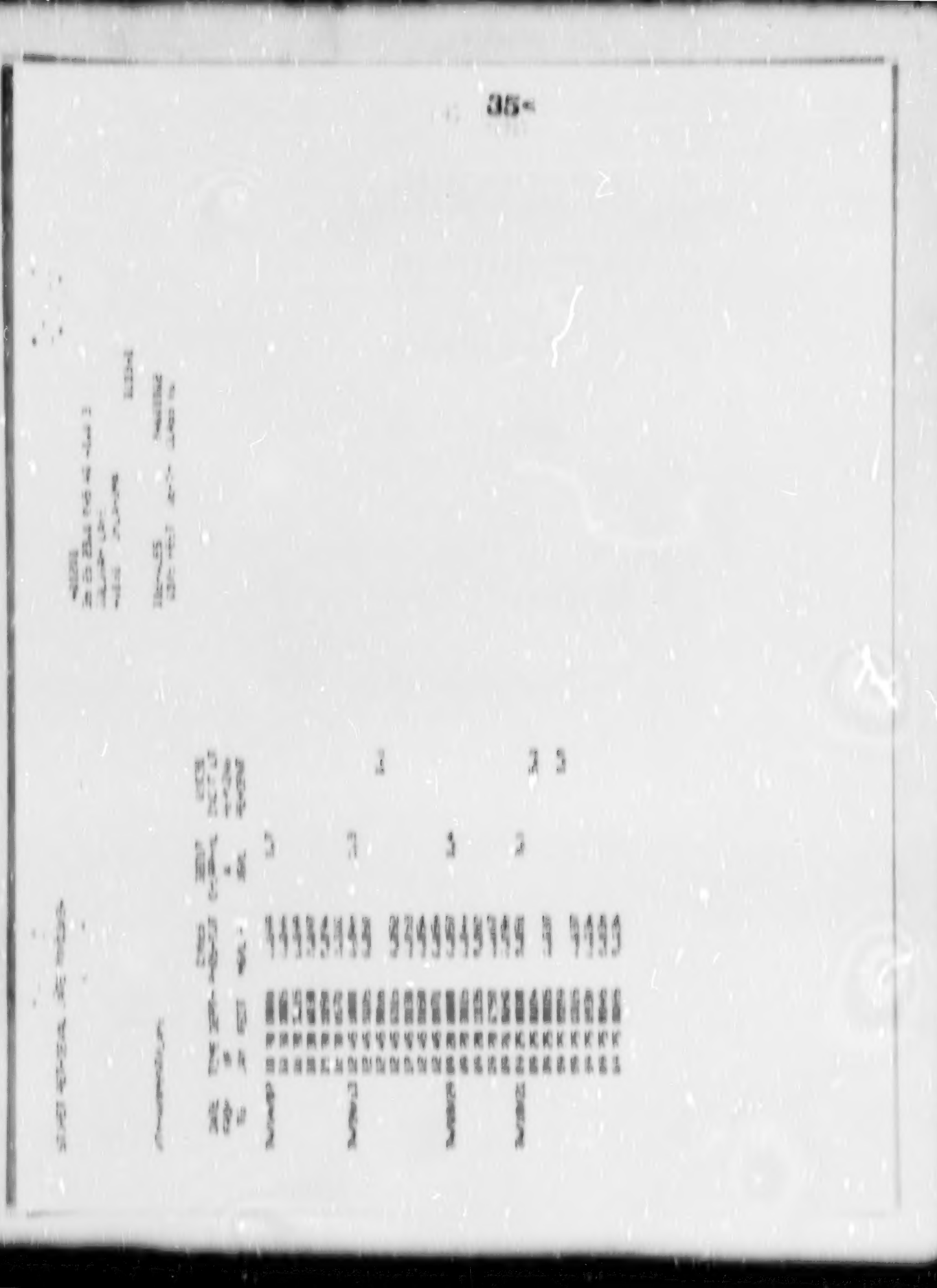
TOTAL FLOW IN = 854.41
TOTAL FLOW OUT = 853.85

[illegible] FLOWS AND ASSOCIATED FLOWRATES

[illegible]	[illegible]	[illegible]	[illegible] FLOW	DAY	FLOW	DAY	FLOW	DAY	FLOW
[illegible]	11	34	421.671	2	54.749				
	12	34	233.487	15	286.713				
	1	35	134.280	14	286.774				
	2	35	212.374	29	183.441				
	3	35	234.835	14	171.174				
	4	35	244.546	19	183.443				
	5	35	42.475						
	6	35	235.847						
	7	35	38.154	24	2.167				
	8	35	1.561	26	1.565				
	9	35	1.464	29	1.8				
	10	35	1.482						
[illegible]	11	34	[illegible]	2	483.249				
	12	34	86.619	24	241.444				
	1	35	42.844	18	45.317				
	2	35	137.467	15	215.774				
	3	35	175.281	16	194.445				
	4	35	42.469	28	41.859				
	5	35	31.224						
	6	35	237.442	13	94.788				
	7	35	12.744						
	8	35	28.579						
	9	35	1.474						
	10	35	1.457						

APPENDIX C
PHYSICAL AND CHEMICAL DATA





[illegible]

[illegible]

DATE	TIME OF	WIND	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	FEET	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
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	[illegible]	[illegible]	[illegible]		

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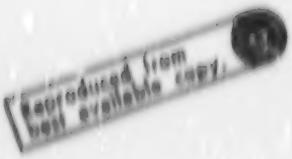
APPENDIX D

TRIBUTARY AND WASTEWATER TREATMENT PLANT DATA



APPENDIX E

PARAMETRIC RANKINGS OF LAKES SAMPLED BY NES IN 1974

STATE OF OKLAHOMA

[illegible] data to be used in [illegible]

LAKE CODE	LAKE NAME	[illegible] TYPE #	[illegible] INDEX #	[illegible] AREA SQ	[illegible] CALCIA	[illegible] PH	[illegible] SITE INTAKE #
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
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TECHNICAL REPORT DATA

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1. REPORT NO.

2.

3. RECIPIENT'S ACCESSION NO.

4. TITLE AND SUBTITLE

Report on Oologah Reservoir, Nowata and Rogers Counties, Oklahoma

5. REPORT DATE

Prepared March 1977

6. PERFORMING ORGANIZATION CODE

7. AUTHOR(S)

Anonymous (National Eutrophication Survey Staff)

8. PERFORMING ORGANIZATION REPORT NO.

Working Paper No. 592

9. PERFORMING ORGANIZATION NAME AND ADDRESS

National Eutrophication Survey
U.S. Environmental Protection Agency
P.O. Box 15027
Las Vegas, NV 89114

10. PROGRAM ELEMENT NO.

11. CONTRACT/GRANT NO.

12. SPONSORING AGENCY NAME AND ADDRESS

Office of Research and Development
U.S. Environmental Protection Agency
401 M Street, S. W.
Washington, DC 20460

13. TYPE OF REPORT AND PERIOD COVERED

Final - 1974

14. SPONSORING AGENCY CODE

15. SUPPLEMENTARY NOTES

Prepared in cooperation with the U.S. Environmental Protection Agency, Corvallis Environmental Research Laboratory, Eutrophication Survey Branch, Corvallis, OR 97330

16. ABSTRACT

Annual total phosphorus and total nitrogen loadings to the lake were estimated and subdivided according to either point or non-point source origin. An assessment of the lake's trophic condition and limiting nutrient is also provided. All data collected by the U.S.E.P.A. National Eutrophication Survey during the one year study of the lake and its tributaries are included in the report.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Eutrophication Lakes Nutrients Phosphorus Nitrogen Loading		05B 05C

18. DISTRIBUTION STATEMENT

Release unlimited

19. SECURITY CLASS (This Report)

20. SECURITY CLASS (This Page)

21. NO. OF PAGES

45

22. PRICE

NTIS

EPA Form 2220-1 (9-73)